Journal of Craniomaxillofacial Research

Vol. 13, Issue. 2 Spring 2026

Zygomatic Implants for the Rehabilitation of Maxillary Defects Post-Mucormycosisy: A Systematic Review

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ARTICLE INFO

Article Type:
Systematic Review

Received: 12 January 2026
Revised: 12 February 2026
Accepted: 19 March 2026

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ABSTRACT

Introduction: Rhino-orbital-cerebral mucormycosis (ROCM) following COVID-19 frequently necessitates extensive, life-saving maxillectomies, resulting in massive anatomical defects that severely compromise masticatory function, speech, and health-related quality of life (HRQoL). Conventional obturator-based rehabilitation is often unpredictable in this cohort due to fungus-induced avascular necrosis of the residual tissue and inadequate basal bone volume. Zygomatic implants (ZIs), by anchoring into the dense, viable cortical bone of the zygomatic arch—anatomically distant from the necrotic maxillary zone—offer a promising graftless reconstructive solution. This systematic review aims to evaluate the survival rate, functional efficacy, and short-term clinical outcomes of ZIs in the rehabilitation of post-COVID-19 mucormycosis maxillary defects.

Materials and Methods: A comprehensive systematic search was conducted across PubMed, Scopus, Web of Science, and Embase, covering publications up to December 2024. Studies were selected based on predefined inclusion and exclusion criteria, focusing on zygomatic implant-based rehabilitation in post-COVID-19 mucormycosis patients. Study selection, data extraction, and qualitative synthesis were performed in accordance with PRISMA 2020 guidelines. Methodological quality of primary clinical studies was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal tools, while review articles were evaluated using a modified AMSTAR-2/SANRA framework.

Results: Twelve studies met the inclusion criteria, comprising 6 primary clinical studies, 4 review articles, and 2 finite element analysis (FEA) studies. The synthesized evidence indicated high primary stability and favorable short-term survival rates for ZIs placed in zygomatic bone anatomically distant from the necrotic maxillary zones. ZIs facilitated rapid functional restoration and demonstrably improved HRQoL in post-mucormycosis survivors. Reported complications included soft tissue dehiscence, oroantral fistulas, and recurrent sinusitis, underscoring the necessity of meticulous surgical planning and structured postoperative follow-up.

Conclusion: Zygomatic implants represent a viable and promising graftless modality for the prosthetic rehabilitation of extensive post-COVID-19 mucormycosis maxillary defects. While short-term functional and biomechanical outcomes are encouraging, the current evidence base is constrained by small sample sizes, predominantly retrospective study designs, and limited follow-up durations. Rigorous, long-term prospective cohort studies are warranted to establish standardized clinical protocols and definitively evaluate the long-term survival of ZIs in this specific patient population.

Keywords: Zygomatic implant; Mucormycosis; Post-COVID mucormycosis.

Please cite this Article as:
Chokami Rafiei S, Fakhri M. Zygomatic Implants for the Rehabilitation of Maxillary Defects Post-Mucormycosis: A Systematic Review. J Craniomaxillofac Res 2026; 13(2): 141-150. DOI: 10.18502/jcr.v13i2.22539

Introduction

These catastrophic surgical defects lead to severe anatomical and functional sequelae, including hypernasal speech, masticatory disability, deglutition impairment, and profound facial disfigurement. Consequently, the patient's Health-Related Quality of Life (HRQoL) is significantly degraded [6,7,8]. Prosthetic rehabilitation for these post-COVID survivors poses unique challenges compared to conventional oncological resections. The vascularity of the residual tissue is highly compromised due to the avascular necrosis induced by the fungus, making the retention, stability, and tissue tolerance of conventional tissue-borne obturators highly unpredictable [7,8]. Furthermore, the lack of adequate basal bone in extensive maxillectomy defects often contraindicates the placement of standard endosseous dental implants. In this complex clinical landscape, Zygomatic Implants (ZIs) have emerged as a promising salvage modality. By engaging the dense, viable cortical bone of the zygomatic arch—anatomically distant from the maxillary necrosis—ZIs can provide immediate, rigid anchorage for obturators or fixed prostheses without the need for extensive, unpredictable bone grafting procedures [9,10]. While the application of ZIs is a well-established protocol in oncology and severe maxillary atrophy, the literature regarding their specific application in the post-COVID mucormycosis cohort is relatively nascent and evolving [11,12]. Recent systematic and narrative reviews have broadly outlined reconstructive options for mucormycosis survivors [11,13]. However, earlier literature frequently mixed general maxillectomy patients with CAM cases, or lacked a dedicated focus on implant-based, graftless rehabilitation. This potentially obscures the specific biomechanical and clinical outcomes related to the CAM population. Therefore, this systematic review aims to critically synthesize the available evidence strictly pertaining to post-COVID-19 mucormycosis patients. The primary objective is to evaluate the survival rate, functional efficacy, and overall prosthetic outcomes of zygomatic implants in rehabilitating complex maxillary defects secondary to CAM.

Materials and Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Search Strategy

A comprehensive electronic search was performed across three major databases: PubMed (MEDLINE), Scopus, and Web of Science, covering the period from the onset of the pandemic (January 2020) to December 2025. The search strategy utilized a combination of Medical Subject Headings (MeSH) and free-text keywords: ("COVID-19" OR "SARS-CoV-2") AND ("Mucormycosis" OR "Black Fungus") AND ("Zygomatic Implant" OR "Zygoma" OR "Maxillofacial Rehabilitation" OR "Obturator"). In addition, a manual search of the reference lists of included articles was conducted to identify any potential studies missed by the electronic search.

Eligibility Criteria

To address the population heterogeneity concern, strict inclusion and exclusion criteria were applied:

- **Inclusion Criteria**

1. Studies involving human subjects with a confirmed history of COVID-19-associated mucormycosis (CAM).

2. Patients who underwent maxillectomy and were subsequently rehabilitated using Zygomatic Implants (either alone or in combination with standard implants).

3. Case reports, case series, and observational studies reporting clinical outcomes (survival, stability, complications).

4. Articles published in the English language.

- **Exclusion Criteria**

1. Maxillectomy defects due to non-COVID etiologies (e.g., Squamous Cell Carcinoma, trauma).

2. Rehabilitation using solely conventional tissue-borne obturators or standard dental implants without zygomatic anchorage.

3. Animal studies, in-vitro studies, and finite element analyses (FEA).

4. Duplicate records or reviews lacking primary patient data.

Study Selection and Data Extraction

Two independent reviewers screened titles and abstracts. Full-text articles of potentially relevant studies were retrieved and assessed against the eligibility criteria. Disagreements were resolved by consensus with a third reviewer. Data were extracted using a standardized form, capturing: Author/Year, Study Design, Sample Size, Defect Type, Number of Zygomatic Im-

DOI: 10.18502/jcr.v13i2.22539

plants placed, Prosthesis Type, Follow-up Duration, and Clinical Outcomes (Survival rate, Complications).

Quality Assessment (Risk of Bias)

Risk of bias and methodological quality of the included studies were rigorously evaluated according to their respective study designs. For case reports and case series (Table 1a), quality assessment was conducted using the Joanna Briggs Institute (JBI) Critical Appraisal Tools and cross-verified with the CARE (CAse REport) checklist guidelines. For review articles (Table 1b), the methodological quality of systematic reviews was appraised using the AMSTAR 2 (A MeaSurement Tool to Assess systematic Reviews) instrument, while narrative reviews were evaluated using the SANRA (Scale for the Assessment of Narrative Review Articles) checklist. Furthermore, for the included computational and biomechanical study (Table 1c), quality was assessed based on specialized parameters for Finite Element Analysis (FEA), including accuracy of 3D modeling, material properties, and loading conditions.

Results

Study Selection and PRISMA Flow

The systematic search across electronic databases initially identified 160 records. After removing duplicates (n = 45), 115 unique records were screened based on titles and abstracts. Of these, 92 records were excluded as they did not meet the primary inclusion criteria (e.g., studies on non-COVID mucormycosis, medical management only, or animal studies). The full texts of the remaining 23 articles were retrieved and assessed for eligibility. During the full-text review, 10 articles were excluded for the following reasons:

1. Wrong Population (Not Post-Mucormycosis): n = 4.

2. Wrong Intervention (No Zygomatic Implants): n = 4.

3. Insufficient Clinical Data: n = 2.

Ultimately, 12 studies met the strict inclusion criteria and were included in the qualitative synthesis. These comprised 6 primary clinical studies (case reports, case series, and clinical trials focusing on ZI/PSI), 4 systematic/scoping reviews and 2 biomechanical finite element analysis (FEA) studies. The selection process is illustrated in the PRISMA flow diagram (Figure 1). Regarding the in silico/biomechanical evaluations, both included FEA studies (Manekar et al. [12] and Rathod et al. [16]) demonstrated a low risk of bias and high methodological quality (Table 1c), having met critical computational criteria including accurate anatomical modeling and physiological force simulation.

Methodological Quality and Risk of Bias Assessment

To address the heterogeneity of the included studies, quality assessment was performed using tools specific to the study design. The Joanna Briggs Institute (JBI) Critical Appraisal Checklist was employed for the 6 clinical studies (Table 1a), while a modified AMSTAR-2/SANRA tool was used for the 3 review articles (Table 1b). For the included biomechanical study utilizing finite element analysis (FEA), methodological quality was evaluated based on standard FEA reporting criteria, specifically assessing the accuracy of 3D model generation, material properties assignment, mesh generation, and physiological replication of boundary and loading conditions (Table 1c).

Study Characteristics and Clinical Outcomes

Data extraction was stratified into three main tables to ensure accurate reporting. Table 2 details the 6 primary clinical studies involving direct patient treatment with Zygomatic Implants or PSI. Table 3 details the findings from the 4 included review articles. Additionally, Table 4 summarizes the parameters and biomechanical findings of the 2 included Finite Element Analysis (FEA) studies.

Synthesis of Findings

1. Survival Rates

Across the primary clinical studies (Table 2), a survival rate of 100% was reported for Zygomatic Implants and Patient-Specific Implants within the reported follow-up periods (ranging from immediate to 24 months). However, these findings should be interpreted with caution due to the predominance of case reports, short follow up durations, and inconsistent reporting of implant survival as a primary outcome. While recent literature heavily focuses on COVID-19-associated cases, valuable biomechanical and functional insights can be drawn from conventional mucormycosis resections. Notably, Abbasi and Alam [15] successfully rehabilitated a severe subtotal bilateral maxillectomy defect (Liverpool Class 2c) resulting from non-COVID mucormycosis. They utilized an asymmetric distribution of three zygomatic implants combined with one infraorbital rim implant, splinted with a Hader bar to retain a customized obturator. Remarkably, this configuration demonstrated robust mechanical stability and optimal retention without any reported complications over an extended 60-month (5-year) follow-up period, proving the efficacy of zygomatic anchorage in severely

compromised bone [15]. The most robust clinical evidence among the included primary studies was provided by a recent double-blind prospective cohort study conducted by Kumar et al. [18]. They rehabilitated 20 post-COVID-19 mucormycosis maxillectomy patients utilizing the quad zygoma concept. The study reported quantifiable improvements in psychological and functional parameters following zygomatic implant placement. Specifically, mean salivary cortisol levels, an objective biomarker for stress, significantly decreased from 22.80 nmol/L before rehabilitation to 8.65nmol/L at the 6-month follow-up ($P < 0.05$). Furthermore, significant improvements were noted in state anxiety levels, masticatory capability, and speech intelligibility.

2. Functional Improvement:

Functional outcomes were consistently superior in the implant group. A studie by Beri et al. [10] highlighted that unlike conventional obturators—which often suffer from leakage and lack of retention in extensive defects—zygomatic implants provided a stable foundation for mastication and speech.

3. Quality of Life (QoL)

Quantitative assessment using the OHIP-14 scale [8] and HRQoL measures demonstrated significant improvements in psychological well-being and social interaction. The systematic review by Cheruvu and Khan [11] (Table 3) further corroborated these findings, concluding that implant-based rehabilitation utilizing approaches like the quad zygoma is a highly predictable method for restoring functional outcomes and QoL in extensive maxillectomy patients.

4. Review Studies Synthesis

Furthermore, the narrative review by Rathee et al. [13] evaluated the spectrum of prosthodontic rehabilitation for post-mucormycosis defects. They concluded that while various obturators (immediate, interim, definitive, and hollow-bulb) are heavily utilized, zygomatic implant-retained prostheses stand out as a highly predictable alternative for patients with extensive bony defects who face retention issues with conventional prostheses.

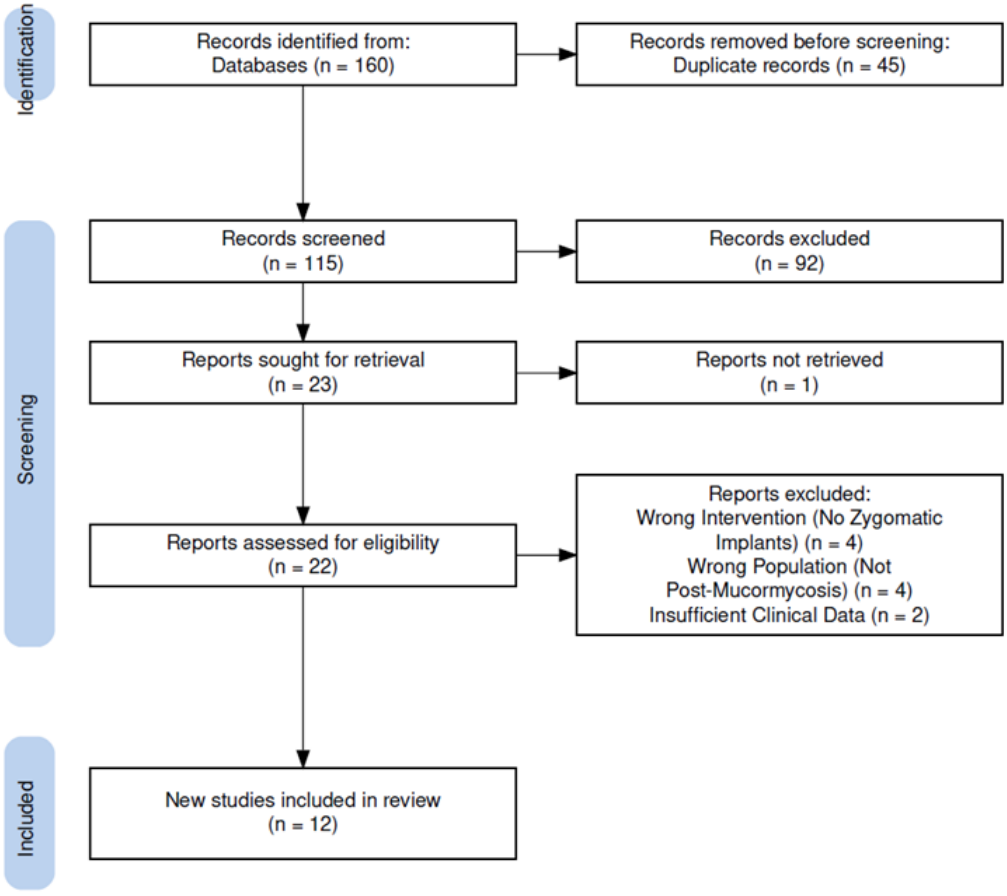

Figure 1. PRISMA 2020 flow diagram illustrating the literature search and study selection process.

- Identification: n = 160.
- Screening: n = 115.
- Included: n = 12.

DOI: 10.18502/jcr.v13i2.22539

Table 1a. Risk of bias assessment for primary clinical studies (JBI Checklist).

Study [Ref]	Study Design	Patient Demographics Clear?	Clinical Condition Defined?	Intervention Protocol Clear?	Post-Intervention Outcomes Clear?	Adverse Events Reported?	Overall Risk of Bias
Saxena D et al. (2024) [6]	Case Report	Yes	Yes	Yes	Yes	Yes	Low
Kawade et al. (2024) [9]	Case Report	Yes	Yes	Yes	Yes	Yes	Low/Mod
Beri et al. (2023) [10]	Case Report	Yes	Yes	Yes	Yes	Yes	Low
Abbasi & Alam (2023) [15]	Case Report	Yes	Yes	Yes	Yes	Yes	Low
Kumar L et al. (2023) [18]	Prospective Cohort	Yes	Yes	Yes	Yes	Unclear (Discussed generally, not patient-specific)	Low Risk of Bias
Arvind et al. (2025) [19]	Clinical Study	Yes	Yes	Yes	Yes	Yes	High

Table 1b. Methodological quality assessment for review articles.

Study [Ref]	Study Design	Research Question Clear?	Search Strategy Comprehensive?	Data Synthesis Valid?	Conclusions Supported?	Overall Quality
Chouksey et al.(2025) [8]	Systematic Review	Yes	Yes	Yes	Yes	High
Deo et al. (2022) [7]	Scoping Review	Yes	Yes	N/A	Yes	Moderate
Cheruvu VPR et al. (2022) [11]	Systematic Review	Yes	Yes	Yes	Yes	High
Rathee M et al. (2022) [13]	Narrative Review	Yes	Yes	Yes	Yes	Moderate to High

Table 1c. Methodological quality assessment of the included biomechanical (in silico) study using fea specific criteria.

Study [Ref]	3D Model Generation	Material Properties Assigned	Boundary Conditions Defined	Loading Conditions (Physiological)	Mesh Generation/Convergence	Overall Methodological Quality
Manekar VS et al. (2023)[12]	Yes (CT derived accurate anatomy)	Yes (Linear, elastic, isotropic)	Yes (Nodes fixed at cranial base)	Yes (Simulated masseter/masticatory forces)	Yes (Validated mesh size)	High (Low Risk of Bias)
Rathod DK et al. (2023) [16]	Yes (CT derived post-mucormycosis model)	Yes (Linear, elastic, isotropic)	Yes	Yes (Occlusal & lateral forces)	Yes	Moderate

Abbreviations: FEA = Finite Element Analysis; CT = Computed Tomography.
Note: Criteria based on standard reporting guidelines for computational and biomechanical studies in dentistry.

Table 2. Characteristics of included clinical and biomechanical studies on zygomatic/PSI implants in post-mucormycosis defects.

Study (First Author, Year)	Study Design	Sample Size (N)	No. of Zygomatic Implants	Defect Etiology	Follow-up (Months)	Clinical Outcome Measures	Complications Reported	Level of Evidence
Saxena D et al. (2024) [6]	Case Report	1	1 (Custom Subperiosteal Zygoma Framework)	Post-COVID Mucormycosis	3	Speech, Mastication, Aesthetics, QoL	Minor regurgitation, wear of attachments	V
Kawade R et al. (2024) [9]	Case Report	1	4 (Quad Zygoma)	Post-COVID Mucormycosis	Immediate / Short-term	Esthetics, Phonetics, Mastication	None reported	V
Beri et al.(2023) [10]	Case Report	1	4 (Quad Zygoma)	Post-COVID Mucormycosis	24	Soft tissue healing, prosthesis stability, aesthetics	None reported	V
Abbasi & Alam (2023) [15]	Case Report	1 patient (65-year-old male)	3 zygomatic implants and 1 infraorbital rim implant	Conventional (Non-COVID) mucormycosis, subtotal bilateral maxillectomy	60	Optimal retention and stability; sustained improvement in speech, mastication, and QoL.	None (only routine maintenance/ replacement of clip riders).	IV
Kumar L et al. (2023) [18]	Single-center, double-blind prospective cohort	20	Quad Zygoma	Post-COVID Mucormycosis (Rhino-Orbital-Cerebral)	12	Salivary cortisol (stress), Appearance Anxiety, Mastication, Speech	None explicitly reported for the cohort	IV
Arvind et al. (2025) [19]	Clinical Study	10	Zygomatic Implants + 3D Patient-Specific Implants (PSI)	Post-COVID-19 Mucormycosis	12	Efficient therapeutic outcomes; favorable scores for implant fit and surgical rating.	Evaluated (pain, infection, exposure) with positive outcomes	IV

Table 3. Characteristics and findings of included review articles.

Author & Year [Ref]	Study Design	Defect Etiology (Focus)	Subjects (N Studies)	Intervention / Treatment (Focus)	Follow-up (Range)	Specific Clinical Outcomes / Conclusions
Chouksey et al.(2025) [8]	Systematic Review	COVID-19-Associated Mucormycosis	8	Prosthetic Rehabilitation (Obturators & Zygomatic Implants)	Varied	HRQOL shows improvement after prosthodontic rehab. Obturators and zygomatic implants are preferred options.
Deo et al. (2022) [7]	Scoping Review	Post-COVID Mucor	42	Management Strategies	N/A	High volume of maxillectomies requires complex rehabilitation; conventional options often fail in large defects.
Cheruvu VPR et al. (2022) [11]	Systematic Review	Rhino-Orbito-Cerebral Mucormycosis	19	Reconstructive modalities (including 4zygomatic implants)	Varied across studies	Highlighted quad zygoma as a viable option for restoring lip support, normal speech, and swallowing; achieving optimal functional and aesthetic restoration.
Rathee M et al. (2022) [13]	Narrative Review	Maxillary defects secondary to mucormycosis (post-COVID-19)	N/A (Narrative Review)	Surgical reconstruction (flaps, CAD-CAM) and Prosthodontic rehabilitation (Obturators, Zygomatic Implants)	N/A	Concluded that while hollow-bulb/inflatable obturators are standard, zygomatic implants serve as a safe, predictable, and cost-effective modality. They specifically overcome severe retention and stability issues in extensive or bilateral maxillectomy defects where conventional prostheses fail

DOI: 10.18502/jcr.v13i2.22539

Table 4. Characteristics and biomechanical findings of the included finite element analysis (FEA) studies.

Study (First Author, Year)	*3D Model Description & Implant Configuration*	*Loading Conditions*	*Maximum Stress Location*	*Key Biomechanical Findings*
Manekar VS et al. (2023) [12]	*Post-COVID Maxillary Mucormycosis Defect (PCMMD). Compared Patient-Specific Implants (PSI struts & screw-retained) vs. Quad Zygoma Implant (QZI).*	*Masticatory load on virtual simulation.*	*Anterior region (specifically for QZI).*	*Demonstrated good resistance to displacement. Stress and plastic strain values were low and physiologically acceptable. QZI showed slightly higher stress concentrations in the anterior region compared to PSIs.*
Rathod DK et al. (2023) [16]	*Simulated post-COVID mucormycosis maxillectomy model; Quad Zygoma configuration.*	*Simulated masticatory forces (Occlusal and laterally directed).*	*Distal head of the zygomatic implants.*	*Maximum stress concentrated at the distal head of ZIs. Stress in the surrounding bone and fixed prosthesis remained well within safe limits, corroborating clinical biomechanical stability.*

Discussion

The precipitous rise in Rhino-Orbito-Cerebral Mucormycosis (ROCM) following the COVID-19 pandemic created a unique cohort of patients with extensive maxillary defects. Unlike typical oncological resections, post-mucormycosis defects are characterized by a compromised vascular bed, severe scarring, and a high risk of osteomyelitis recurrence. Conventional rehabilitation with tissue-borne obturators often fails in these cases due to the lack of adequate hard tissue undercut, oro-nasal leakage, and poor retention, leading to significant psychological morbidity [6,7]. This systematic review synthesized data from 12 included studies (6 primary clinical studies, 4 systematic/scoping reviews And 2 in silico finite element analysis (FEA) studies.) to evaluate the efficacy of Zygomatic Implants (ZI) and Patient-Specific Implants (PSI) as a viable alternative.

Biological Rationale and Implant Survival

Furthermore, recent advancements have expanded treatment options; for instance, Saxena et al. [6] demonstrated the successful application of a 3D-printed, patient-specific subperiosteal zygoma implant (psSPI) for cases where extensive necrosis precludes traditional quad zygoma placement. A critical consideration in the rehabilitation of maxillectomy defects is the long-term survivability of zygomatic implants in functionally compromised bone. The structural limitations of soft-tissue flaps in severe maxillary defects necessitate advanced graftless reconstructive strategies.

As highlighted by Beri et al. [10], the quad zygoma approach provides a robust alternative for massive defects, particularly in CAM patients, allowing for early temporization and minimizing the adjunctive surgical burden. While Beri et al. [10] documented a highly successful 24-month complication-free follow-up for a CAM patient rehabilitated with four zygomatic implants, the most extensive long-term survivability data is still primarily derived from the non-COVID cohort. For instance, Abbasi and Alam [15] demonstrated a 60-month follow-up with no significant complications in classic mucormycosis, underscoring the pressing need for extended longitudinal studies (beyond two years) specifically targeting CAM survivors.

Functional Restoration and Quality of Life

The transition from “preservation of life” to “restoration of quality of life” is the primary challenge in post-COVID mucormycosis management, prompting a necessary shift from conventional obturators to prosthetically driven reconstructions. To scientifically validate the stability of such advanced approaches, a finite element analysis (FEA) by Manekar et al. [12] evaluated the biomechanical response of the Quad Zygoma Implant (QZI) versus patient-specific implants (PSI) specifically in post-COVID maxillary mucormycosis defects (PCMMD). Their virtual simulation confirmed that QZIs offer commendable resistance to displacement with low and acceptable stress and strain values under masticatory loads, although slightly higher stress concentrations were noted in the anterior re-

gion compared to PSIs. Furthermore, the systematic review by Cheruvu and Khan [11] and recent clinical evaluations corroborated these findings, concluding that utilizing approaches like the quad zygoma is a highly effective and predictable method for restoring adequate lip support, speech, and functional outcomes in critically compromised patients. Similarly, a robust finite element analysis by Rathod et al. [16] evaluated the stress distribution of quad zygomatic implants in a simulated post-mucormycosis maxillectomy model (summarized in Table 4). Their findings revealed that while the maximum stress under simulated masticatory loads is concentrated at the distal head of the zygomatic implants, the stress values within the surrounding bone and the fixed prosthesis remain within safe physiological limits. This biomechanical validation strongly corroborates the clinical success observed in the quad zygoma approach, proving that the intact zygomatic bone can effectively dissipate occlusal forces even when the primary maxillary support is completely lost due to necrosis.

The transition from conventional prosthetic rehabilitation to implant-supported solutions marks a significant paradigm shift in managing post-mucormycosis defects. As highlighted by Rathee et al. [13], traditional hollow-bulb or inflatable obturators, while effective in providing an immediate oro-nasal seal, often present long-term challenges related to weight, patient comfort, and retention, particularly in limited mouth opening scenarios. In contrast, they emphasized that zygomatic implants offer a safe, predictable, and cost-effective treatment modality. By bypassing the need for extensive bone grafting in the depleted maxilla and utilizing the pristine dense bone of the zygomatic arch, this approach provides superior retention, stability, and ultimately, an enhanced quality of life for survivors of extensive bilateral maxillectomies [13].

In extensive defects (Class III and IV), the weight of a conventional obturator often compromises retention. The clinical reports included in this review, such as Beri et al. [10], confirm that ZIs provide the rigid fixation necessary to support a lightweight, fixed, or removable prosthesis that does not rely on soft tissue support. This is particularly relevant for mucormycosis survivors who often have friable, thin palatal mucosa that cannot tolerate the load of a heavy obturator. The aggressive nature of COVID-19-associated mucormycosis does not spare younger demographics. In a case presented by Beri et al. [10], a 32-year-old male with extensive bilateral maxillary defects was successfully rehabilitated using a quad zygoma approach. The implants were immediately temporized within three days, highlighting the primary stability achieved by engaging the dense malar bone even in massive defects. While initial literature predominantly consisted of case reports and series, the recent prospective cohort study by Kumar et al. [18] significantly elevates the level of evidence regarding zygomatic implants in post-mucormycosis defects. By evaluating a larger sample size (N = 20) and utilizing objective quantitative markers (e.g., salivary cortisol levels), this study objectively validates the subjective clinical observations reported in earlier case studies, confirming that zygomatic implant-supported prostheses not only restore biomechanical function but also drastically reduce psychological stress in maxillectomy patients.

Building upon standard zygomatic implant protocols, recent technological advancements have introduced customized CAD/CAM reconstructive solutions. A recent clinical study by Arvind et al. [19] evaluated the integration of zygomatic implants with 3D-manufactured patient-specific implants (PSIs) in 10 post-COVID-19 mucormycosis patients. By assessing parameters such as implant fit, facial edema, and orbital status over a 12-month follow-up, the authors reported highly efficient therapeutic outcomes. This integrative approach represents a significant evolution in managing complex, individualized midfacial defects, offering precise anatomical adaptation alongside the robust biomechanical anchorage of zygomatic implants.

Clinical Relevance: Patient Selection and Protocols

Based on the synthesis of the included studies, specific clinical guidelines emerge for practitioners:

Timing of Placement: Implants should only be placed after the complete resolution of the fungal infection is confirmed clinically and radiographically, typically requiring a disease-free interval.

Surgical Approach: For sub-total or total maxillectomy defects where conventional implants are impossible, the Quad-Zygoma approach or Zygoma-Pterygoid combination is recommended.

Digital Workflow: The use of PSI (Patient-Specific Implants), as demonstrated by Arvind et al. [19], offers a solution for complex anatomical distortions where standard ZIs may be difficult to position. This highlights the necessity of CBCT planning and 3D modeling in this specific population.

DOI: 10.18502/jcr.v13i2.22539

Limitations of the Review

Despite the promising results, this review has several critical limitations that must be acknowledged, addressing the concerns regarding the level of evidence:

Low Level of Evidence: The majority of the included clinical data (6 studies) consists of case reports and small case series (Level IV/V evidence). There are currently no randomized controlled trials (RCTs) comparing ZIs with conventional obturators in post-mucormycosis patients.

Short Follow-up Durations in Post-COVID Cohorts: A notable limitation across the reviewed literature is the predominance of relatively short follow-up periods (ranging from 6 to 24 months) for COVID-19-associated mucormycosis. Currently, rare long-term observations in the literature—such as the highly successful 5-year follow-up documented by Abbasi and Alam [15]—are derived from conventional (non-COVID) mucormycosis cases. This scarcity of longitudinal data specifically for the post-COVID cohort highlights the need for larger, prospective studies to comprehensively evaluate late complications, such as peri-implantitis or delayed hardware failure, in this specific patient population.

Heterogeneity: While we excluded general atrophy cases to focus on mucormycosis, the extent of defects varied (from partial to total maxillectomy), which influences the biomechanical load on the implants.

Publication Bias: The absence of reported failures in the literature may reflect a publication bias, where unsuccessful cases of ZI in mucormycosis patients are less likely to be published.

Conclusion

Within the limitations of the current evidence base, the following conclusions can be drawn:

1. Zygomatic Implants represent a viable and predictable treatment modality for the rehabilitation of post-mucormycosis maxillary defects, offering superior retention and stability compared to conventional obturators.

2. Short-term survival rates are high (100%) in the reported literature, largely due to the engagement of the uninfected zygomatic bone.

3. Quality of Life is significantly enhanced through the restoration of speech and masticatory function, justifying the surgical complexity in eligible patients.

However, Zygomatic Implants should not be blindly labeled as the "gold standard" until long-term, prospective studies with larger sample sizes validate these findings. Clinicians must exercise rigorous patient selection, ensuring disease resolution and utilizing digital planning tools to minimize surgical risks.

Conflict of Interest

There is no conflict of interest to declare.

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